Serendipitous Data Following a Severe Windstorm in an Old-Growth Pine Stand

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Abstract

Reliable dimensional data for old-growth pine-dominated forests in the Gulf Coastal Plain of Arkansas are hard to find, but sometimes unfortunate circumstances provide good opportunities to acquire this information. On July 11, 2013, a severe thunderstorm with high winds struck the Levi Wilcoxon Demonstration Forest (LWDF) near Hamburg, Arkansas. This storm uprooted or snapped dozens of large pines and hardwoods and provided an opportunity to more closely inspect these rare specimens. For instance, the largest tree killed in this event, a loblolly pine (*Pinus taeda*), was 105 cm in diameter at breast height, 39.3 m tall, and if the tree had been sound would have yielded 3,803 board feet (Doyle log rule) of lumber. Gross board foot volume yield was also estimated from two other recently toppled large pines, an 85-cm-DBH loblolly and an 86-cm-DBH shortleaf pine (*Pinus echinata*), which tallied 2,430 and 2,312 board feet Doyle, respectively. A number of the other wind thrown pines on the LWDF were sound enough to count their rings for a reasonable (± 2-5 years) estimate of their ages. The stump of the fallen national champion shortleaf pine had 168 rings, and counts from other pines toppled by this storm had from 68 to 198 rings. We also searched for a new champion shortleaf pine using a LiDAR canopy height model of the LWDF to narrow our search. This preliminary assessment produced a number of targets that exceeded 40 m in height; further field checking of the tallest of these trees found that these were loblolly pines up to about 44 m. We eventually found shortleaf pines between 37 and 41 m tall, with diameters of up to 85 cm, indicating that the LWDF could still contain the Arkansas state champion.

Introduction

The scarcity of forests that can be considered representative of "virgin" timber limits our ability to get many desirable kinds of quantitative data, such as stand density, maximum tree size, age class distributions, and species composition. Hence, evidence adapted from old sources is an important supplement for researchers interested in restoring stands using historical forests as a guide. However, historical documentation presents a number of challenges to its application, many of which have been described elsewhere (e.g., Egan and Howell 2001, Bragg 2004b), including the difficulty of confirming the validity of the data. For example, it was common practice for people to write the board foot lumber volume of felled trees or logs on old photographs (Figure 1). Using the men in this picture for scale can help evaluate the lumber volume written on this photograph, but it is not possible to confirm the value given because of insufficient information on the length and diameter of this log.

Figure 1. A pine log from Ashley County, Arkansas, with the quantity of lumber estimated to be sawn from this log written on the photograph (1,684 board feet). Copy of a historical postcard courtesy of the Crossett Public Library.

While it is unlikely researchers will be able to unequivocally prove the claims of most of these unscientific documents, it may be possible to find contemporary trees that could confirm or refute the information presented. It is therefore critical to take advantage of every opportunity to collect such data in modern-day forests, especially given the rapid degradation of the resource due to management practices and biological processes. One such opportunity arose recently at the Levi Wilcoxon Demonstration Forest (LWDF) in Ashley County, Arkansas. The LWDF is a small remnant stand of pine-dominated old-growth that has been studied in recent years, both before and after a recent restoration thinning conducted by the current landowner (Bragg 2004a, 2006, 2010). On July 11, 2013, a severe thunderstorm with high winds struck the LWDF, uprooting or snapping dozens of large pines and hardwoods, including the national champion shortleaf pine (*Pinus echinata*). Though the loss of these big trees was unfortunate, it allowed us to more closely inspect these unique specimens.

Methods

Site description

The ~60 ha LWDF is located ~6 km south of Hamburg, Arkansas. This stand has been described in detail in previous research (e.g., Bragg 2004a, 2006, 2010), so only a brief description will be included in this paper. Following a restoration harvest in 2009-2010, the LWDF's overstory basal area is now over 83% pine, primarily loblolly (*Pinus taeda*), with a prominent shortleaf pine component (Bragg 2010). The LWDF is dissected by a number of small ephemeral streams. The gently (<2% slopes) rolling Calloway and Grenada silt loam (Glossic Fragiudalfs) soils found on the LWDF are seasonably wet. Locally, the annual precipitation averages about 140 cm and there are 200 to 225 frost-free days (Gill et al. 1979). The LWDF was protected as an informal "natural area" by the Crossett Lumber Company in 1939 (Anonymous 1948). Over the intervening decades, the only consistent management treatments conducted in this stand have been the occasional salvage of dead or dying pines (Bragg 2004a, 2006).

The windstorm that damaged the LWDF in July 2013 was a small, localized event that primarily affected the southeastern portion of this stand, with some additional damage near the parking lot and picnic tables just north of the juncture of Highways 425 and 52. We did not attempt to document all felled trees from this event; rather, we identified a non-random subset of the toppled pines for further description (see next sections for details).

Board foot lumber estimation

One goal of this effort was to determine if the lumber estimates found in historical photographs are reasonable approximations or gross exaggerations. In the days following the storm, a field crew from the U.S. Forest Service visited the LWDF to scale the board foot lumber volume of three very large pines (two loblolly, one shortleaf) that had fallen to the ground. Starting at "stump height" (approximately 30 cm above the former ground line), we measured outside-bark diameter (DOB) every 1.22 m along the merchantable portion of the bole across two axes using a large set of calipers—these values were then averaged to produce a mean DOB for that segment. We also cut into the bark at each location to estimate its thickness at that point, which was then subtracted to produce the inside-bark diameter (DIB).[1]

The fallen pines were then apportioned into 3.7 m to 4.9 m sawlogs[2] until their stems got too branchy for utilization (historically, lumber operations did not utilize the entire tree, but only took sawlogs to the point that removing the limbs with hand tools became too time consuming or unwieldy). Log volume estimates were adapted from Table 7 in Mesavage and Girard (1946, pgs. 15-16) for 4.9-m-long logs, using the smallest DIB from the two cut ends of the log. This table applies the Doyle log rule, which was one of the most commonly applied log scaling rules for this part of the United States well into the 20th Century (Freese 1974). Because lumber yield (English units) has no direct conversion to metric cubic volume measures (e.g., Fonseca 2005), log volume estimates in this paper have been reported in terms of board feet (Doyle log rule).

Pine age estimation

Following salvage operations (which commenced within weeks of the storm event), we returned to the LWDF to count the rings on any pine stumps that were sufficiently sound. Rings were tallied for two different radii of each stump; the values were then averaged and rounded off to the nearest ring. Although loblolly and shortleaf pine have prominent annual growth rings, they may have false or missing rings that can affect aging of trees and must be corrected with cross-dating to produce a date of origin. However, we did not cross-date the rings; therefore, these estimates are probably within 2 to 5 years of true tree age.

Champion shortleaf pine search

In addition to the volume and age samples, we searched the LWDF to see if a replacement champion

Figure 2. A pre-storm aerial photograph of the LWDF showing the forest structure and extent of the search area (light gray line).

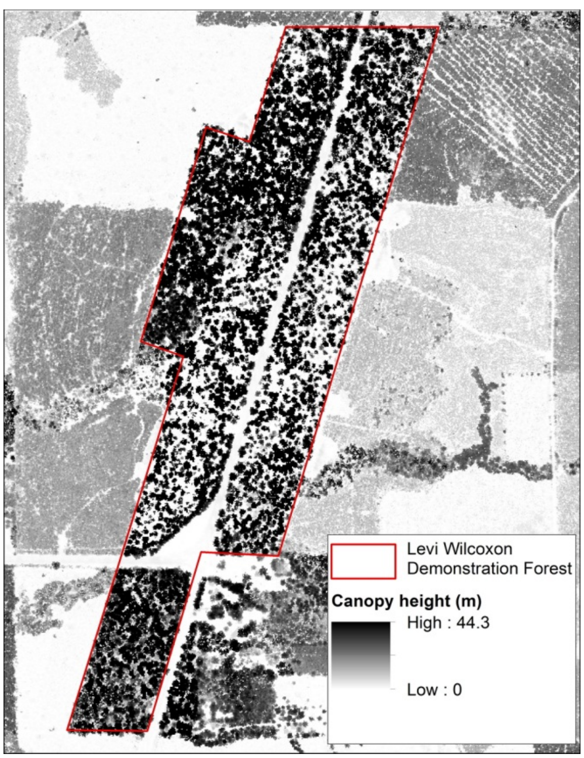

Figure 3. A LiDAR canopy height model of the LWDF with all heights shown.

shortleaf pine could be found. The search for a new champion was no small task—the forest area of the LWDF covers over 50 hectares with plenty of tall pines, including scores of shortleaf pine (Figure 2). To facilitate our search for a new champion, we obtained LiDAR data flown during winter 2011-2012 with average point spacing of 1.0 m through the USGS Earth Explorer (http://earthexplorer.usgs.gov/).

We then used Fusion software (McGaughey 2014) to produce a canopy height model (Figure 3) with 2-m pixels of LWDF and adjacent lands; this produced a map of the LWDF that could then be used as a guide to concentrate on areas with a higher probability of finding very tall trees. Previous experience in the LWDF suggested that shortleaf pine >38 m were present; we thus used this height threshold to classify favorable search locations (Figure 4).

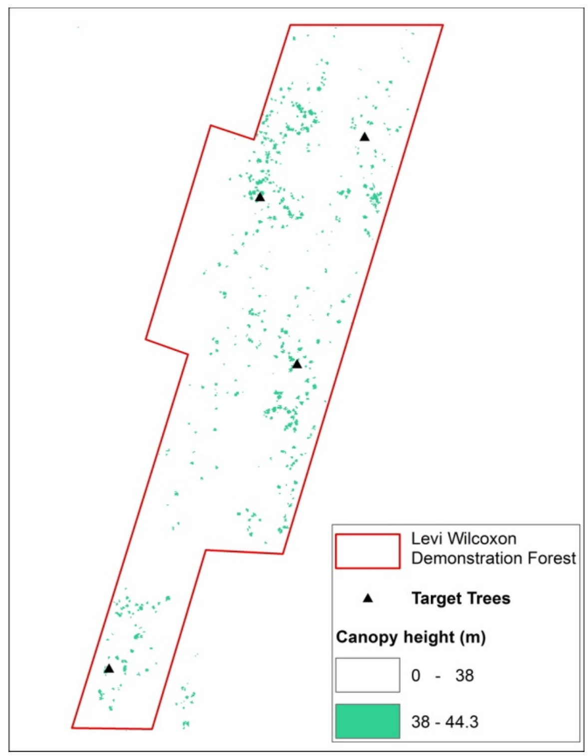

Figure 4. The LWDF LiDAR canopy height model with only heights greater than 38 m highlighted and the four target trees identified.

While it helped focus our search, LiDAR alone was insufficient for identifying champion trees for several reasons. First, LiDAR measures canopy height rather than tree height; these measures may differ where the ground is sloped and may not strike the highest point on the individual crowns (Kelly et al.

2010). Second, LiDAR does not provide any independent taxonomic information—if there is no clear stratification of the canopy by taxa, the remotely sensed data cannot distinguish tree species.

Third, in addition to total tree height (*HT*, in feet) the index used to determine champions (*AFBI*, American Forests 2014):

$$AFBI = CBH + HT + \frac{1}{4}\, CS \qquad (1)$$

also incorporates crown spread (*CS*, in feet) and stem circumference at breast height (*CBH*, in inches), the latter of which cannot be measured with the requisite accuracy from remotely sensed data.

We transferred the spatial coordinates of the four tallest trees identified by the model to a Garmin eTrex GPS. In the field, we located these highest LiDAR hits and searched the surrounding areas for large shortleaf pines. We used either a TruPulse 200 (with built-in clinometer) or a Nikon Prostaff 440 laser rangefinder (with a separate Suunto clinometer) to measure heights of potential champion trees with the sine method (Bragg 2008). Diameter at breast height (DBH) was measured at 1.37 m above ground and then converted to circumference for CBH. Because of time constraints, we only measured crown spread (the average of the widest and narrowest spread of the live tree crown) for the five largest shortleaf pines and one post oak (*Quercus stellata*).

Results and Discussion

Evaluation of lumber volume

We examined the largest tree killed in the July 2013 windstorm, a loblolly pine 105 cm in DBH and 39.3 m tall, for its lumber yield. This specimen had a gross sawtimber yield of 3,803 board feet (Doyle log rule) of lumber in four 4.9-m-long sawlogs (which tallied 1,050, 961, 942, and 900 board feet, respectively). For perspective, a typical 38-cm-DBH pine with three 4.9-m sawlogs (more consistent with trees produced by modern-day plantations) would yield 121 board feet. It is important to note that the 3,803 board feet assumed the pine was sound (i.e., it did not lose volume due to decay and defect). This particular loblolly pine did have extensive butt rot, so its net yield would have been significantly lower (we did not determine net yield). The low bole taper of this loblolly pine is also apparent from the modest decrease in board foot volume in each sawlog—the smallest log is only about 14% less than the biggest.

The gross Doyle log scale results for the other two pines were noticeably lower but followed similar patterns. The 85-cm-DBH loblolly pine was 38.7 m tall before it fell; this specimen was estimated to yield 2,430 board feet from four 4.9-m and a single 3.7-m sawlog (610, 571, 511, 467, and 271 board feet, respectively). The 86-cm-DBH shortleaf pine was 39.6 m tall, and had an estimated 2,312 board feet in five 4.9-m sawlogs (655, 566, 441, 361, and 289 board feet, respectively).

All of these pines had additional log volume that was not included in this assessment because they would have had too many branches to have been utilized in historical lumbering operations. Though our results cannot confirm the accuracy of the stated tree volumes on any historical photographs (e.g., Figure 1), they do suggest that these claims are plausible. Sawtimber yields of the largest pines from the Upper West Gulf Coastal Plain of Arkansas, Louisiana, and Texas have been given in the historical literature between 7,000 and 11,000 board feet Doyle (e.g., Record 1910, Morbeck 1915, Chapman 1942, Bragg 2002). A sign on the 142-cm-DBH Morris Pine, the oldest and largest living loblolly pine in the LWDF, reports a volume of 5,000 board feet (Bragg 2002).

Although these values are substantially higher than our estimates, they also came from pines with much bigger boles that probably had more sawlogs. Loblolly pines exceeding 150 cm in DBH and over 45 m tall have been documented in this region and shortleaf pine greater than 100 cm in DBH and over 40 m tall are also possible (e.g., Mohr and Roth 1897, Chapman 1942, Bragg 2002); it is almost certain that these species probably exceeded even these values. Very large, columnar, branch-free boles helped to accentuate the sawtimber volume yield of the virgin timber. As an example, one such loblolly pine from central Louisiana that scaled over 10,000 board feet was 137 cm at DBH and 102 cm in diameter at 29.3 m above the stump (Chapman 1942).

Pine age estimates

The extensive basal bole decay (butt rot) found in the LWDF limited the number of pines that could have their age estimated via ring counts. However, enough sound trees were found to show a poor (but positive) relationship between stump diameter and estimated pine age (Table 1). The youngest pine (a loblolly) examined had 68 rings; the oldest (a shortleaf) yielded 198 rings, and the former national champion shortleaf was estimated to be 168 years old when it was killed in this storm (Table 1). The former national champion shortleaf pine happened to grow on a favorable site by

Table 1. Stump ring counts for pines killed by the July 2013 windstorm at the LWDF.

Species	------ Average stump ------ diameter (m)	ring count
Shortleaf pine	1.00	198
Shortleaf pine	1.12	168*
Shortleaf pine	0.72	160
Shortleaf pine	0.81	148
Shortleaf pine	0.79	147
Shortleaf pine	0.87	144
Shortleaf pine	0.62	139
Shortleaf pine	0.56	133
Shortleaf pine	0.77	126
Shortleaf pine	0.77	108
Shortleaf pine	0.65	89
Shortleaf pine	0.52	81
Loblolly pine	0.70	186
Loblolly pine	1.16	160
Loblolly pine	0.72	134
Loblolly pine	0.68	116
Loblolly pine	0.52	68

* Former national champion shortleaf pine.

a small ephemeral stream, which probably accounts for its larger size and relatively fast growth.

The limited age data available for the LWDF from past research (e.g., Bragg 2004a, Bragg 2006, Bragg 2010) found similar spans of ring counts—between 50 and 170 for dominant and codominant pines. Bragg (2004a) suggested that some of the standing live loblolly and shortleaf pines that either yielded incomplete cores or were too decayed to even attempt to core were 200 years of age, and that the oldest loblolly pine on the LWDF, the Morris Pine, probably exceeded 300 years. The presence of a 186-ring loblolly and 198-ring shortleaf pine in the current sample (Table 1) support these assertions. We did not examine any of the windthrown hardwoods following this storm event for their ages; it is expected from earlier work (Bragg 2010) that the larger hardwoods in the LWDF are about as old as the dominant pines.

It is important to note that none of these samples were randomly chosen and, hence, these should not be construed as representative of the LWDF's actual age class structure. However, the limited information available continues to suggest that the lack of discrete age cohorts and the wide span of the ring counts support the hypothesis that the virgin pine forests in this part of the Arkansas Gulf Coastal Plain were largely uneven-aged, with the notable exception of areas struck by catastrophic disturbances such as fires or tornadoes (Chapman 1912, Forbes and Stuart 1930, Turner 1935, Bragg 2002). Severe wind events such as the July 2013 storm and a similar May 2003 storm that occurred in a different part of the LWDF (Bragg 2004a) impact relatively small patches and often leave individual pines or small groups of pines largely unscathed. Such heterogeneity helped to structure the virgin pine forests of the region (Chapman 1912, Bragg 2002), particularly when coupled with other natural processes such as fire and insect-related pine mortality.

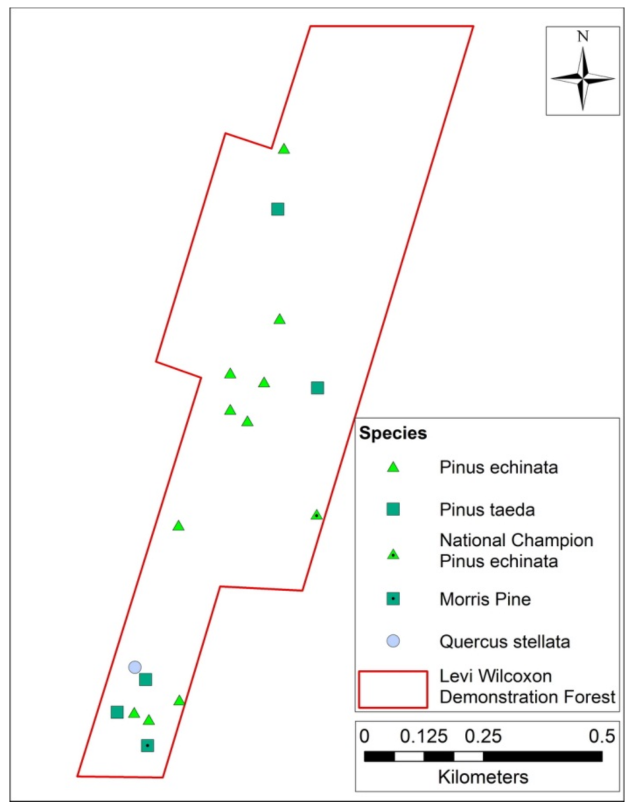

Figure 5. Locations of the field-measured tall trees from the LWDF reported in Table 2. This map includes the locations of the Morris Pine and the former national champion shortleaf pine.

LiDAR search for a new champion shortleaf pine

According to the LiDAR canopy height model, much of the LWDF has trees that exceed 38 m in height (Figure 3). Hence, our search for a new shortleaf pine champion concentrated on distinct parts of the stand surrounding four target trees, three in areas of generally high canopy and an isolated tall specimen tree (Figure 4). All four target trees proved to be loblolly pines, which we measured on-site using laser

Table 2. Tree size measurements taken at the LWDF while searching for a new champion shortleaf pine; columns with English units provided because this is how the AFBI is calculated.

Common name	Height (m)	DBH (cm)	Crown spread (m)	Height (ft)	CBH (in)	Crown spread (ft)	AFBI[1]
Loblolly pine	44.1	98.4	--[2]	144.7	121.7	--[2]	--[2]
Loblolly pine	43.1	101.5	--	141.5	125.5	--	--
Loblolly pine	43.0	91.3	--	141.0	112.9	--	--
Loblolly pine	42.5	94.3	--	139.3	116.6	--	--
Shortleaf pine	40.9	68.5	--	134.1	84.7	--	--
Shortleaf pine	40.5	76.7	12.9	133.0	94.9	42.2	238
Shortleaf pine	40.2	78.3	11.4	132.0	96.8	37.5	238
Shortleaf pine	39.9	77.9	11.8	131.0	96.4	38.8	237
Shortleaf pine	39.6	67.2	--	130.0	83.1	--	--
Shortleaf pine	39.6	78.0	12.2	130.0	96.5	40.1	236
Shortleaf pine	39.3	69.7	--	129.0	86.2	--	--
Shortleaf pine	37.8	85.3	13.4	124.0	105.5	44.1	241
Shortleaf pine	37.8	75.2	--	124.0	93.0	--	--
Shortleaf pine	36.7	80.2	--	120.3	99.2	--	--
Post oak	34.2	68.7	11.8	112.3	85.0	38.6	207

[1] AFBI = American Forests bigness index (American Forests 2014) = total tree height (in feet) + stem circumference (in inches) at 1.37 m above groundline (CBH) + ¼ crown spread (in feet).

[2] Crown spread was measured only on the 5 biggest shortleaf pines and the post oak; AFBI is therefore only calculated for these 6 trees.

rangefinders as 42.5 to 44.1 m tall (Table 2). Under most circumstances, loblolly is larger in girth and taller than shortleaf pine (Baker and Langdon 1990, Lawson 1990), so this result was not surprising. Loblolly pines over 42 m are exceptional for upland sites in southern Arkansas, but not nearly the tallest recorded; this species has been documented to exceed 52 m on large river bottomlands in the eastern part of its range (Native Tree Society 2009).

After confirming that the tallest LiDAR returns were all loblolly pines, we then searched other parts of the stand for big shortleaf pines. The removal of most of the hardwood midstory during 2009-2010 greatly facilitated our field-based search by making crowns more visible and easier to measure. Dozens of shortleaf pines were examined for their potential champion status; Table 2 provides the 10 most notable specimens (these, as well as the four large loblolly pine targets and the large post oak, can be found in Figure 5). These shortleaf ranged in height from 36.7 to 40.9 m; DBHs ranged from 68.5 to 85.3 cm; and crown spreads ranged from 11.4 to 13.4 m. Under national (and most state) champion lists using AFBI points, trees within five points of each other qualify as co-champions, and the five largest shortleaf pines fell within the 236 to 241 point range. Though impressive, none of these shortleaf reached the stature of the former champion, which measured 91.4 cm DBH (or 287 cm [113 inches] CBH), 41.5 m (136 ft) tall, with a 15.2 m (50 ft) crown spread and produced a AFBI score of 262 points when nominated in 2006 (American Forests 2014).

Even though most of the overstory hardwoods at the LWDF were removed in a restoration harvest conducted several years ago (Bragg 2010), a number were retained throughout the stand. These include some of considerable size, including one post oak we measured at 34.2 m tall and 68.7 cm DBH, with an average crown spread of 11.8 m (a total of 207 AFBI points; Table 2). The currently listed Arkansas state champion post oak is 31.1 m tall, with a 147.1 cm DBH and an average crown spread of 31.7 m (310 AFBI points). Large forest-grown specimens such as the post oak measured on the LWDF often fail to make champion lists because they tend to be tall but with less bole girth and (typically) much narrower crowns than trees growing in the open.

Conclusions

Our results indicate that many historical sources of tree dimensions in the pine-dominated forests of southern Arkansas are reasonable in their claims. For example, based on his observations of the virgin forest, Mattoon (1915) had placed the maximum height threshold for old shortleaf pine at just under 40 m with diameters of 60 to 90 cm and ages of 200 to 300 years as being "common"; the evidence from the LWDF suggests that these are acceptable restoration targets for most sites in southern Arkansas. This is encouraging because we are rapidly running out of examples of very large trees in today's highly modified landscapes. The loss of mature, pine-dominated forests of natural origin across the southeastern United States is a major conservation concern. In particular, the decline of shortleaf pine across the coastal plain, including that in southern Arkansas, presents a challenge for our understanding of the mechanism(s) behind this change, as well as reasonable measures for successful restoration efforts.

We believe the outcomes reported in this paper speak to the need for researchers to closely monitor any remnant tracts of old-growth timber for similar opportunities to quantify the structural and composition attributes of these stands. Many of these remnants are understandably protected to a degree that limits the ability of scientists to gather certain types of information—their scarcity supports extra caution to minimize any threats to their health and integrity. The deaths of these dwindling examples of large, old loblolly and shortleaf pines in the Upper West Gulf Coastal Plain is an unfortunate loss that can be somewhat offset by capturing whatever information we can from these trees before it is lost to decay or salvage.

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Endnotes

[1] Bark thicknesses ranged from 0.25 to 1.8 cm, depending on the location on the bole. Bark is thicker nearer the lowest portion of the bole, and thinner further up the stem.

[2] Sawlog lengths are another unique attribute of historic lumber information; hence, the rather curious metric lengths for some logs. For instance, a 3.7-m log is 12 feet long, and a 4.9-m log is 16 feet long.

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